USDA Agricultural Research Service
a
National Program
304 Crop Protection and Quarantine
External Review Assessment

December 2013

National Program 304
Crop Protection and Quarantine

Table of Contents

Executive Summary

Insect and weed pests exacerbated by the constant influx of new invasive species, pesticide resistance, changes in climate and water constraints continue to pose a significant threat to efficient, economical and environmentally sound agricultural production. USDA's mission is to provide national leadership for agriculture, and the USDA ARS is the agricultural research and information arm of the federal effort to safeguard American agriculture. The USDA ARS National Program 304 on Crop Protection and Quarantine is where stakeholder-driven research on insect, mite and weed pest management is centered. The program is a critical component of our national pest management capacity with unique expertise, core capacities and infrastructure that gives support to a wide range of federal and state action agencies, as well as university and industry partnerships.

A new PCAST report[1] identified "managing new pests, pathogens, and invasive plants" as a top agricultural priority for the 21st century, and recent experiences with the invasive spotted wing drosophila that threatens production losses of $718 million in 12 East Coast states[2] and in the West Coast[3], and $207 million glyphosate-resistant Palmer amaranth (a spreading weed problem in cotton and soybean in the South[4] and elsewhere estimated to cost growers in Georgia alone $110 million annually[5]) make these new threats real. Therefore, it is critical that NP 304 continue to receive the support needed from the agency to function effectively as an indispensable partner in the effort to protect US agriculture and natural resources from pest threats, and perhaps more significantly, be spared from management and budget decisions that could disproportionally impact this program going forward.

A retrospective review of NP 304 accomplishments was carried out by an external panel of experts in a teleconference on December 11-12, 2013 (see the report for a list of panel members). The assignment was to provide a high level, but critical, overview of the program based on a review of project accomplishments prepared by ARS program staff (*National Program 304: Crop Protection and Quarantine Accomplishment Report 2007-2012*) with the corresponding action plan (*National Program 304: Crop Protection and Quarantine Action Plan 2008-2013*) as a background document. Primary and secondary reviewers were assigned to every project in the accomplishment report prior to the virtual meeting so that preliminary draft observations could be shared with the entire review team during the review discussion. The review team arrived at a consensus position, which is presented here in the Executive Summary with details in the attached report. Most members found the review process significantly flawed, which prompted a statement about this process following the Executive Summary.

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[1] The President's Council of Advisors on Science and Technology. 2012. *Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise*.
[2] Spotted Wing Drosophila Working Group. 2012. *Spotted Wing Drosophila Impacts in the Eastern United States.* 8 pp. http://www.sripmc.org/WorkingGroups/eFly/Impacts%20of%20SWD%20in%20the%20Eastern%20US%202012.pdf
[3] Bolda, M.P., R.E. Goodhue and F.G. Zalom. 2010. *Spotted wing drosophila: potential economic impact of a newly established pest*. Agricultural and Resource Economics Update 13 (3):5-8.
[4] Sosnoskie, L.M and A.S. Culpepper. 2014. *Glyphosate-resistant Palmer amaranth (Amaranthus palmeri) increases herbicide use, tillage and hand-weeding in Georgia cotton*. Weed Science 62: in press.
[5] A.S. Culpepper personal communication.

The review team was impressed with the reported accomplishments, and gives the program an overall rating of high to medium-high with room for improvement in some areas (the team reported seven highs, four medium-highs and two mediums; see the report for details). Many, perhaps most, projects had achievements that reached far beyond the reported accomplishments; a good example is the work on brown marmorated stink bug (BMSB) spearheaded nationally by ARS that was not readily apparent in the accomplishment report. The NP 304 program provides unique core capacities and fundamental infrastructure that are vital to the national pest management community, i.e., systematic expertise and collections, classical biological control, postharvest quarantine, overseas labs, natural products such as pheromones, kairomones, and botanicals, area-wide management, resistance monitoring and management, resistance breeding and long-term initiatives among others. These capabilities allow ARS to embrace some high risk, long-term activities that are critical for a national pest management effort.

In review team discussions, there was a sense of a perceived imbalance in efforts between entomology and weed science given the low number of ARS scientists working on weed problems, and the relatively low number of weed management accomplishments listed in the accomplishment report. We surmise that this could reflect an historical difference in ARS efforts between entomology and weed science, but it may also reflect demand, and any changes probably should be determined by clientele needs and management, rather than by a scientific review panel. The involvement of ARS scientists in graduate training was praised as a strategy for the agency to stay connected with the cutting-edge science being done at universities, while maintaining a balance between basic and applied research that cuts across both organismal and sub-organismal systems, particularly in areas where the agency has core competencies and unique infrastructure.

It is clear from the documents and our personal experiences that ARS scientists in NP 304 cooperate and collaborate with other federal and state action agencies, universities and industry. These collaborative partnerships create synergistic relationships that complement specific expertise and multiply the impact of individual institutional efforts. Given the extent and importance of these interactions, it was surprising to find that some significant collaborations were not clearly documented in the accomplishments. Many of the action agencies rely entirely on the R&D output of the program for new tools and technologies needed to address emerging issues. It is the partnerships with universities, especially those in the Land Grant University system, and with industry that help keep the science current and relevant. Given the importance of these collaborations, especially with the continuing financial and operational constraints, it makes sense for ARS to leverage expertise and capacity where they can, provide adequate visibility and credit to all involved, and use this approach as a model for future programs.

One way to institutionalize these efforts would be to develop a research strategy that defines IPM as an overarching principle. Such a strategy could be used to determine when and where to pursue specific tactics/approaches that take advantage of core competencies, fundamental infrastructure and key partnerships. New technologies and knowledge generated by research programs offer some remedy, but individual components are far less effective if they are not considered as part of an overall strategy embodied in IPM. The overall strategy should explicitly describe collaborations, divisions of labor, communication mechanisms, and collaborative planning and evaluation procedures including intended outcomes and performance measures.

The following are some specific observations that emerged from our discussions worth considering. While the insect and pathogen research collections themselves are an ongoing process and, therefore, do not necessarily involve cutting edge research, they provide an invaluable and necessary resource without which top-level research on microbial control agents would be impossible. In addition, the phylogenetic analyses and development of analytical tools used by curators and their collaborators are state of the art and have provided major insights concerning the identification, systematics and host interactions of microbes with potential for safe and efficacious insect and weed control. Interagency linkages should be evaluated to provide for better adoption of ARS research results, and to ensure that ARS strengths and talents are most efficiently employed. Provide research support for USDA NRCS technical and financial assistance programs that encourage farmers to participate in promising area-wide and other IPM programs. Note the legislative mandates that link ARS to IR-4 for future reviews. While EPA 'section 18' applications are not activities normally expected from ARS scientists, there should be flexibility to allow for this on a case by case. Host-specificity testing of candidate biocontrol agents is a unique capacity ARS should embrace as central to the viability of our national classical biocontrol efforts. ARS does not have the expertise necessary to work with every system, but is well positioned to network with agency and university colleagues to be effective. Current research in natural environments focuses mostly on control, but should also consider restoration, landscape processes and change management as elements of these projects in the future. In the area of postharvest quarantine, two action areas of critical importance to further develop include pest inspection/detection methods and systems approach applications.

Finally, we include a number of considerations for your next meeting with stakeholders and development of your next five-year plan. Invasive species should continue to receive dedicated attention and scrutiny given the importance of global trade. Urban and natural environments provide a rich array of new R&D opportunities with growing stakeholder demands; however, not every consideration will be possible. Therefore, ARS should be strategic about expanding the scope and leverage when and where possible, particularly where activities are a high priority and core competencies are involved. An exciting new area of science is the role of microorganisms in facilitating a wide range of interactions between hosts, pests and natural enemies. Consider adding new efforts that look at the interactions of microbes with their hosts from the microbiome level all the way up to entire ecosystems. Continue to embrace molecular tools and technologies without giving up organismal and population level research across all components of your projects; e.g., RNAi and other emerging technologies as tools for managing resistance. It is important to maintain a proper balance in expertise and approach to assure the range of capabilities needed to address new and emerging issues. Explicitly include research on ecosystems and ecosystem services; e.g., non-target impacts including pollinator health with IPM systems. And in a related effort, continue and enhance the Long-Term Agro-Ecosystems Research Network to parallel the Long-Term Ecological Research (LTER) Network created by the National Science Foundation.

ARS External Review Process

The review team was unanimously frustrated in our effort to properly evaluate the program accomplishments and impacts given the information provided in the *National Program 304: Crop Protection and Quarantine Accomplishment Report 2007-2012* and the corresponding *National Program 304: Crop Protection and Quarantine Action Plan 2008-2013*. This prompted considerable discussion among panel members, especially those of us who have served on ARS review panels before and were surprised to see the same recurring issues. What follows are some observations and considerations on how to improve the process.

Observations:

- The Action Plan is an excellent document and provides a good basis for assessment. However, the materials provided for review do not facilitate a thorough assessment by someone who is not an expert linked with the problem area.
- It was difficult to connect the pieces because the action plan and accomplishment report did not group activities/project in the same way.
- In some cases the accomplishment report significantly understated the real accomplishments of projects as measured by collaborations and publications.
- Where collaborations were evident, it was not always clear what their relative roles and contributions were.
- There was minimal attention given to tech transfer and outcomes/impacts throughout the documents.
- By focusing uniquely on accomplishments, the program ignores pertinent issues; e.g., budget cuts, lab closings, project reassignment/closures, etc., that can effect stated goals.

Considerations:

- Improve the accomplishment report by reporting against the stated outcomes in the action plan. Where possible, distinguish between scientific accomplishments and impact, rather than trying to force the reporting of accomplishments as impacts.
- A more effective report would explicitly list anticipated products and potential benefits for each project, and compare performance measures including number of projects, participation measures (e.g., scientists, funding), outputs, products and outcomes to these expectations and to these measures for other reporting periods
- Outputs are reported with very limited reference to outcomes, i.e., if the ultimate outcome is that the pest no longer remains a threat, what is the contribution of the output to that goal?
- Organize larger sections of the report into sub-categories. This will facilitate compiling the document and give projects the attention they deserve.
- Clearly show collaborations both within and outside of USDA.
- Make use of contemporary knowledge discovery technologies, such as topic modeling and knowledge network analysis, to demonstrate the breadth, foci, networks and gaps in the current research portfolio.

NP 304 Component 1 – Systematics and Identification

Problem Statement 1.A: Insects and Mites

Review Team Rating (Impact): Medium-High

Review Team Assessment:

Systematics work performed on fruit flies and tortricid moths revealed habits common to phylogenetic species groups. These relationships aid Plant Health regulators in their consistent efforts to estimate the risk posed by potential plant pests with poorly documented biology by extrapolating likely behavior from better-known sibling species. The fruit fly work revealed potential contributions to biological control programs by documenting species complexes within rather confined feeding niches, although this work might have been better substantiated if the researchers had employed more than a single CO1 genetic region.

Other work completed during the period focused on specific regulatory problems. Interactive taxonomic keys, for example, to the economically important beetle genus *Diabrotica* and to longhorned beetles of Hispaniola, aid regulators in assessing pest risk posed by potential pathways of introduction of exotic pests and in recognizing introduced pests. As US demand for year-round availability of fresh fruits and vegetables increases, plant health officials require considerably more knowledge of risk posed and pathways to the US for exotic pests expected to cause high adverse impacts if established here, as provided by ARS work on the New World tomato fruit borer. In another example, ARS research has helped industry and the State of Washington to differentiate apple maggot from snowberry maggot, which generate cost savings as noted in the accomplishment report, but also can significantly increase revenue by facilitating export of apples.

As taxonomic expertise and resources continue to decrease, current and comprehensive reviews of large taxonomic groups increase in value. The Diptera catalog covering Mexico and Central America provides a foundation for the study of this large and diverse taxon. The online diagnostic tool for *Anastrepha* provides the means to identify over 250 species in this economically important genus. This tool will facilitate world trade in numerous fruits by allowing differentiation of non-regulated from regulated species of *Anastrepha* in national and industry efforts to document geographical pest freedom.

In support of biological control programs, ARS contributions offer varied impacts. ARS identifications are a critical early step or certification requirement toward establishing new programs, as in the cases of the cycad mealybug predator, the Brazilian peppertree moth and Australian dung beetles. Other projects may provide less immediate impact, as in the initiative that discovered 34 new insect species in Argentina with potential as biocontrol agents. However, such projects are difficult to evaluate for impact within a few years of publication due to the long-term nature of biological control development and implementation. In addition to the few projects selected for documentation in the accomplishment report, ARS published dozens of other projects supporting biological control efforts.

Problem Statement 1.B: Weeds

Review Team Rating (Impact): Medium-High

Review Team Assessment:

A fundamental basis for sustainable pest management systems is an understanding of the biology of the pest targets. This includes correct identification of the pest species. Historically, identification was based upon morphological characteristics, but now molecular genetics techniques can provide more conclusive identification and separation of species. In addition, these techniques can provide insight into evolutionary processes, crossing between species, and invasion pathways.

Controlling invasive weeds on millions of acres of land in the US has proven difficult. Where biological control is an option for control of these plants, selecting effective and acceptable biological control agents involves considerable expense and time. Taxonomic work is an absolute prerequisite to minimize the cost and time required to obtain authority to release these agents. Accurate identification of weed species, strains and hybrids facilitates search, discovery, testing and justification of potential biological control agents for invasive weeds. The difficulty in identifying different weeds from among morphologically similar taxa can require lengthy and complicated taxonomic and behavioral investigation, like that on prickly ash performed by ARS.

NP 304 researchers applied molecular diagnostics to solve varied, practical weed control problems. The accomplishments document lists four items as representing the impact of activities in this area: a scholarly review of molecular methods for biological control of weeds, work on vegetative and reproductive characteristics of prickly nightshades (*Solanum*) species, population genetics of Canada thistle (*Cirsium arvense*), and genetic analysis of saltcedar (*Tamarix ramosissima* and *T. chinesis*) populations.

Molecular differentiation of plants has proved more difficult than for other organisms like insects and fungi. Strides in this area could significantly facilitate identification of difficult groups. The review of molecular methods is certainly useful as a reference and is notable in the inclusion of authors from the United States, France, Australia and a private international foundation. The review of molecular methods for fighting invasive weeds constitutes a logical step toward more effective means of distinguishing sibling species, hybridized populations and origins of weeds. However, it is not as impactful as would be the actual utilization of these methods to attack a problem. That said, the accomplishments using these techniques to address Canada thistle and saltcedar are very important. Both of these represent widespread and noxious invasive weeds and the accomplishments of the cited studies could be important for establishing biological control for these species. Potential adverse impact on native thistles of releasing biological control agents for Canada thistle has slowed or threatened program progress in the US for decades. Molecular markers developed by ARS produced a phylogeny that showed previously released biological control agents do not harm native thistles – a finding that should help to reduce criticism of and resistance to the thistle control programs. The research also identified Eurasia as the origin of Canada thistle in North America, which could lead to discovery of additional thistle control agents. The saltcedar work is also notable in that it suggests hybridization between the two saltcedar species that may explain the invasiveness of these species. Predicting the invasive potential of introduced plants is very important and this study shows that not only should founder species be considered, but also potential hybrids between species. The work on nightshades is less immediately impactful but it is also the type of information often lacking, but needed for developing new management systems.

Problem Statement 1.C: Insect and Weed-Associated Microorganisms

Review Team Rating (Impact): Medium-High

Review Team Assessment:

USDA entomopathogen collections are a vital national resource for research on microbial control agents. The value of the collections has exponentially increased because recent technological improvements in molecular analysis provide enormous potential to screen, select and evaluate species and strains for microbial control of insect pests.

Support for maintenance and use of official microbial germplasm collections is the focus of this problem area. The availability and quality of *Bacillus thuringiensis* and comprehensive Entomopathogenic Fungal Culture collections provide a resource for conducting highly practical research. ARS has added 3,200 isolates to the Entomopathogenic Fungi collection, which now totals over 12,000 isolates; 2,800 samples have been shared with the research community in the past 5 years. The collection has been used for major revisions of entomopathogenic fungi. Six new species of the important entomopathogenic genus *Beauveria* were discovered in a major revision of the genus using molecular data from several genes. Sixteen species of insecticidal fungi in five genera were cultured from coffee berries. ARS scientists discovered a critical enzyme produced by some strains of *Bacillus thuringiensis* that is related to toxic crystal production. Strains without urease can reproduce in the host, but do not possess the insecticidal toxins. Work with *Bt* varieties identified naturally occurring gypsy moth pathogens capable of surviving in the environment. New methods for predicting host specificity of pathogens facilitated the identification and evaluation of new pathogens of several invasive weed species, and will facilitate predictions of efficacy and ecological host range.

The examples of experimental work presented in the accomplishment report, in both “Component 1C” and “Component 2B: Insects”, highlight the importance of the USDA-ARS managed microbial collections. Because chemical pesticides continue to come under scrutiny for environmental damage (including soil degradation and broad impacts on non-target species; food safety issues; and host resistance), the development of controls derived from naturally occurring pathogens is increasingly important. Much of the formulation and efficacy research conducted under “Component 2B: Insects” depend on the availability of a variety of pathogen species and strains to develop the most efficacious control methods.

The highlighted research provides evidence that the collections continue to be expanded, evaluated phylogenetically and biologically, and shared with the global research community. While the collections themselves are an ongoing process and, therefore, do not necessarily involve cutting-edge or applied research, they provide an invaluable and necessary resource without which top-level research on microbial control agents would be impossible. Additionally, the phylogenetic analyses and development of analysis tools that the curators and their collaborators have conducted are state of the art, and have provided major insights concerning the identification, systematics and host interactions of microbes with potential for safe and efficacious insect and weed control. “Component 2, 2B: Insects” covers use of the ARS insect virus collection.

To elucidate impact, the five-year accomplishment report should briefly describe the infrastructure of the collections and, if possible, provide examples of research projects that are supported by the collections. For example, the insecticidal fungi recovered from coffee berries should now be evaluated within a biological control research component for efficacy against coffee berry borer, and the purpose (and possibly the outcomes) of the studies disclosed to the fungi collections unit as a permanent and reportable record.

NP 304 Component 2 - Protection of Agricultural and Horticultural Crops

Problem Statement 2.A: Biology and Ecology of Pests and Natural Enemies

- Weeds

Review Team Rating (Impact): High

Review Team Assessment:

Understanding the biology and ecology of target pest species is the second step, after correct identification of the pests, to creating sustainable management systems. The accomplishments list includes activities that would roughly be categorized into the physiology of weed species, crop responses to weeds and management systems, and biopesticides for weed management. While the work in these areas is significant, as discussed below, other than the first grouping, these do not relate to the Problem Statement of the Biology and Ecology of Pests and their Natural Enemies. It would seem that the last three would fit better with “control”.

Two crucial aspects of weed physiology, regeneration of plants from vegetative organs and seed dormancy, are addressed by projects cited in the accomplishment report. Greater understanding of both these phenomena would, potentially, open up novel approaches for weed management. If either vegetative propagation or seed dormancy could be directly manipulated, then weed populations could be managed in entirely new ways. In addition, these studies contribute to greater understanding of basic plant biology. For example, the findings on adventitious bud dormancy are being used to enhance cassava productivity in Nigeria. In a second example, the work with seed dormancy in red rice is directly related to addressing pre-harvest seed sprouting in cereal crops. Red color and sprouting tendency are linked traits. In addition, while not mentioned in the accomplishment report, red color and sprouting are also linked to susceptibility/resistance genes for head scab, a serious disease of small grains. If these traits could be separated, then progress on breeding for head scab resistance could be accelerated.

The second series of studies under this area deal with the mechanisms of glyphosate resistance in weed species. Cited projects have identified or elucidated on target site amplification, target site modification, and/or altered glyphosate absorption and movement as bases for glyphosate resistance in weeds. While these projects have importance in understanding resistance mechanisms to this specific and very important herbicide, they also both illustrate aspects of basic plant biology and add to the diversity of mechanisms for evolving herbicide resistance.

On the subject of crop responses to weeds and management systems, the accomplishment report lists what is likely to be seminal work in this area. The papers cited under “Mechanisms of weed-induced yield losses identified” help establish that there are crop responses (gene expression alteration) that are separate from responses to weed competition with the crop for resources (light, water, nutrients). While competition for resources is still a factor, non-competitive interactions could play a role in the effects of low weed populations, below what would be considered competitive, on crop yields. These effects have been one reason thresholds have been difficult to employ for weed management. Manipulation of crop genetics to avoid these non-competitive effects could result in more “competitive” crop varieties. This work also sheds additional light on plant-plant interactions.

A second accomplishment in this area is establishing that annual crops used as nurse crops can help in the establishment of perennial grasses for restoration of disturbed land in the Northern Great Plains. These findings will counter concerns of practitioners that the annual crops inhibited establishment of the perennial grasses and will help protect soil from erosive losses.

Herbicide selectivity, where the desirable crop is unharmed and target weeds are killed by herbicides, is the basis for much of modern weed management. The accomplishments list details work to understand and alleviate lack of selectivity in sweet corn to several herbicide classes. The project identifies a single, or closely related, cytochrome P450 enzyme(s) responsible for herbicide detoxification in this crop. Use of this information will allow more efficient breeding for maintaining herbicide selectivity in this crop. However, this information has the potential to shed light on the “promiscuity” of P450 detoxification enzymes, plus may indicate that weed species could develop resistance to multiple herbicide classes through modification of one P450 enzyme.

Finally, in the area of biopesticides, two projects are cited. The first deals with engineering sorghum and other species to produce the allelochemical sorgoleone. This is a continuation of a long-running effort with the potential to be a paradigm shift, crops producing their own weed-inhibiting chemical rather than herbicide applications. While there are several questions relating to this technology, the effort has produced significant results. Beyond the weed management implications, the results could help manipulate other plant pathways and a novel enzyme for potential use in oilseed plants. The second project deals with culturing microbes to produce bioherbicides. An inhibitor (regulator) of the bioherbicide production was identified. While this has application to the specific system studied, it may also help with regulation of other microbially produced products.

Problem Statement 2.A: Biology and Ecology of Pests and Natural Enemies

- Insects

Review Team Rating (Impact): High

Review Team Assessment:

The ARS scientists worked successfully at several levels of organization, including the molecular, organismic, population and ecosystem levels. It is important to maintain this balance, especially because ARS has an almost unique ability to be able to marshal large-scale field studies.

ARS scientists have identified unusual new ways of possibly modifying insect biology to the detriment of the pest species. Examples include aphrodisiac compounds, neuropeptides, inducible antifeedants and chemicals involved in insect immunity, diapause disruption, and regulation of excretion. New bioactive chemicals that are unique to arthropods potentially provide greater selectivity, and less hazard to vertebrates and other non-target organisms. Linkage with industry early in the developmental process is important in gauging the economic feasibility of such research. RNAi research seems to be receiving surprisingly little emphasis.

Insecticides and bioinsecticides have long been the principal tactic used for insect suppression, but resistance to these insect control agents is increasing in severity, including within genetically modified crops. ARS research is seeking greater understanding of how resistance develops within insects. This will foster practices that should prolong the utility of insect control products.

The use of insect natural enemies has long been a priority, and although parasites are most often used to manage insect pests, predators often show greater resilience and sustainability. However, assessment of the role of predators has been difficult, and ARS research on prey DNA does much to enhance our understanding and usability of predators for biological control. This technology is being adopted world-wide, and shows potential for rapid integration into cropping systems. It is being used for studies of predator conservation, but also needs to be applied to assess the benefits of predator augmentative release. The role of insect learning in enhancing insect management remains interesting, but elusive from a practical perspective.

Pests occur on a landscape level, not just in individual fields, and agriculturalists are slow to appreciate the benefits of area-wide management, and how climate change may affect the nature of pest problems (also note that landscape configuration affects pollinators and biocontrol organisms). Important insight has been gained via research on tarnished plant bugs, fall armyworms and stink bugs – insects that move long distances or infest a large number of plants. Also, significant progress has been made on increasing our understanding of the interaction of pest insects with alternate crop and weed hosts. While always an important factor, alternate hosts have greatly increased in importance due to the discovery of the important role of weeds in harboring plant diseases that are then moved into the crops. Also, climate change will affect the abundance of plants, possibly causing shifts in floral communities and insects inhabiting them. Examples of critical research include whiteflies on sweet potatoes and tarnished plant bug on cotton.

Developmental research that shows less immediate benefit, but which may ultimately prove important, includes new methods to detect pheromone receptors, and the importance of trace metals in insect diets.

Problem Statement 2.B: Control

- Weeds

Review Team Rating (Impact): High

Review Team Assessment:

The accomplishments in this area deal with management systems for managing weeds, discovery and development of new herbicides, and the potential for bioenergy crops to become invasive weeds. All of these have significant implications for future weed control.

Diversification of control tactics is a key tenet for sustainable weed management systems and there are three projects cited which, directly or indirectly, can be used to increase diversity in weed management systems. The “Population-based weed management system” combined several cultural approaches (crop rotation, narrow crop rows, increased seeding rates, fertilizer placement) with a modified tillage system (no-till) to reduce the need for herbicide applications in Great Plains cropping systems. This resulted in a net saving of $15-$25 per acre for the growers. While the report emphasized the reduced herbicide use, the increased diversity in the weed management system is even more notable. Another notable part of this study was the identification of seed predators that reduced the weed seed bank. Effective manipulation to reduce the weed seed bank could completely alter the intensity of weed management practices required for efficient crop production. The review also noted that ARS may be ideally suited, more than some university programs, to conduct long-term cover crop and other crop management studies and is encouraged to do so.

A second project worked to develop organic weed management systems for no-till soybean production in the mid-Atlantic region. These systems relied upon cover crops and crop rotation to achieve weed control. And, while these systems were aimed at organic production, they also have direct applicability to non-organic systems.

A third project that diversified weed management tactics examined herbicide options for kudzu control. This is a very troublesome invasive weed, particularly, in the Southeast and other parts of the U.S. While there are herbicides and other options for controlling this weed, additional alternatives would diversify the approaches for management and work to combat evolution of resistance in this weed. The project found that combinations of herbicides were superior to individual products applied alone for managing kudzu. One potential criticism of all three of these projects might be that they are relatively or very location specific. However, by their nature, weed management and cropping system solutions are very geographically restricted.

A fourth project listed in this section deals with controlling algae in California rice fields. While it may be debatable whether this is a “weed control” issue, the results from this work have clearly been very beneficial to rice farmers and have reduced the need to use algaecides.

Three projects were concerned with discovery and development of biologicals for direct use as herbicides or as leads for discovery of new herbicide chemistries. This work is critical because no new herbicide mode of action has been introduced in the past 25 years. There are several reasons for this, but identification of additional chemistries for weed control would be one step to correct this. Additionally, there is an urgent need for effective biologicals for weed management in organic cropping systems. All of these projects could address that need. In addition, the impact of this work is increased through partnerships with commercial companies for the development of the new chemistry.

Finally, the last area cited in the accomplishment report deals with the potential for biofuel crops to become invasive. This is a critical question for weed scientists and was made even more pressing with recent federal rules allowing planting of several biofuel species of concern. This work also has the potential to be used in assessing the invasive potential of any plant species before it is introduced. This is often a contentious issue in the horticultural trade that wants to bring foreign plants into the US for ornamental use. Most of our invasive weeds and many of our most damaging weeds were introduced. The reviewers emphasized that the results of these assessments for potential biofuel crops to become invasive must be considered before these crops are approved for use in policy decisions. The recent approval of *Arundo donax* planting as a biofuel crop in Florida raises questions as to whether this is actually the case.

The reviewers recognized that weed management on crop fields, whether by herbicides or other management tools, can impact broader ecosystems and affect ecosystem services. Assessments and management of these impacts are primarily the responsibility of federal agencies, such as the EPA, other than ARS. However, ARS is encouraged to cooperate with these agencies in making these assessments.

Problem Statement 2.B: Control

- Insects (IPM)

Review Team Rating (Impact): High

Review Team Assessment:

ARS NP 304 scientists are working in several diverse areas of insect pest management, and they have accomplished a great deal.

Many projects had immediate impact and were very productive having both national and international impact. Examples of projects with immediate and significant impact were the brown marmorated stink bug, sweet potato germplasm identified for resistance, integrated pest management of the sweetpotato whitefly, spotted wing drosophila management, genetic markers developed for rapid optimization of insect artificial diets, decision support systems to efficiently manage key insect pests of wheat and sorghum, new species of biological control agents against olive fruit fly discovered, released, and established, managing the insect vector of zebra chip disease of potato, and area-wide control of fruit flies in Hawaii.

Innovative projects that have demonstrated significant impacts under this problem statement were further endorsed by their uptake by other institutions. For example, the area-wide control of fruit flies in Hawaii is a project that has both national and international implications with the original system that was developed in Hawaii being adopted by other nations across the Pacific. Significant cost savings in rearing the flies on a new liquid diet was adopted by 13 institutions. This project also properly credits collaborators and showed the taxpayer how different institutions can efficiently work together.

More details would have been useful in the project summaries for the work on exploiting host finding and flight behavior of ambrosia beetles, and managing exotic scarabs and root weevils with botanical extracts and reduced-risk insecticides. Many of the projects have benefitted from collaborations within ARS, and with partners in LGUs and industry. These collaborations are adequately explained in only a few project reports. Other evidence of collaborations came from external sources.

To address the diversity of projects in this problem statement, the projects were grouped into the following thematic areas (consider this grouping for future accomplishment reports):

1. Monitoring including remote sensing, improved scouting and decision support systems.
    a. Projects: Sorghum and wheat pests, multispectral analysis of wheat.
    b. Improved information garnered through field observations and decision paradigms that process the information into management activities is the heart of any IPM program. New technologies such as remote sensing coupled with population modeling and traditional scouting provide this information. This effort is in line with the use of 'Big Data' to help solve problems. As techniques are developed to 'mine' extensive databases for patterns and relationships in agriculture, the development of data gathering approaches is paramount. However, once a technology has been developed it needs to be turned over to the implementers whether extension or industry.
2. Integration of components into an IPM approach.
    a. Projects: Fruit flies in Hawaii, sweetpotato whitefly in cotton, stage dependency of tarnish plant bug, spotted wing drosophila, small scale farm sweetpotato IPM, zebra chip vector, disease vectoring thrips, ambrosia beetles, scarabs and root weevils.
    b. Individual pest species interact with other pest species, biocontrols, plant physiological factors, as well as, farm management philosophies and economics, so component technologies must be considered in this IPM context. No one individual, laboratory or institution is capable of addressing an entire pest issue, so it is imperative that well-organized teams be assembled to allow integration of their individual efforts. Perhaps the best example of this is the Hawaiian fruit fly project. Unfortunately, many of the other projects only described rather narrow technology development without much description of how that technology was associated with the entire effort.
3. Area wide control.
    a. Projects: Codling moth and pear esters, fruit flies in the Pacific.
    b. Area-wide control of insect pests has been a visible success for projects associated with ARS. These projects have taken advantage of ARS, Land Grant Universities and industry collaborations. They would not have succeeded otherwise, and these collaborations need to be described here. This should remain a potent strategy for the future.
4. Resistance monitoring and management.
    a. Projects: Insecticide resistance in tarnish plant bug, cereal aphis overcoming HPR.
    b. The development of resistance monitoring tools is very good. Investment should be expanded to investigating resistance patterns for transgenic crops such as Bt corn against rootworm as well as the new RNAi technology.
5. Pheromone/kairomone/botanical discovery and development.
    a. Projects: BMSB, hibiscus mealybug, Superlure, dogwood borer, spotted wing drosophila, pear ester, pear psylla, citrus pheromones, black walnut aphid.
    b. This kind of activity is needed and should continue, but definite guidelines should be established about when the pheromone gets passed off to the next stage of testing/implementation/commercialization.
6. Host plant resistance.
    a. Projects: Sweetpotato germplasm screening, Russian wheat aphid biotype identification.

   b. HPR is tailor-made for ARS because the high-risk and long-term nature of variety development is part of the ARS strategy.
7. Insect diet development.
   a. Projects: Genetic markers for rapid diet evaluation.
   b. Lab-reared insects are essential to support IPM research throughout the world. However, it looks like the ARS role in this arena has run its course.

Problem Statement 2.B: Control

- Insects (Biological and Semiochemical Controls)

Review Team Rating (Impact): Medium

Review Team Assessment:

Overall, the projects dealing with pheromone technology are very impressive, but progress on other projects using more traditional biocontrol approaches were not, most likely reflecting a declining investment resulting in lab closed and staff transfers. Also, the area where classical biocontrol has advanced as a science is in its adoption of molecular genetics for guiding foreign exploration; these projects are presented in Component 1.

Several new pheromone products have been developed and patented for use with either monitoring or enhancing control by natural enemies, and in control. Some of these products are exemplary in that they have provided an alternative to pesticides that is economical and more environmentally friendly. For example, the new navel orangeworm lure and disruption system will save much money for a large industry (1.5 million acres of almonds, valued at 4 billion dollars) with many growers, and has already reduced thousands of pounds of pesticide applications. Other pheromones have been developed for pests of crops with much less acreage and value, or that are still in development with regard to control potential. Some of the newly discovered pheromones or semiochemical mixtures have been under study for years, and show much potential for control strategies, but have yet to demonstrate economical benefits for both conventional and organic produces. Discovery of a lacewing attractant led to an award in Technology Transfer, and involved a large-scale organic producer.

Methods have been developed to extend the shelf life and storage of several fungal biocontrol agents. This has allowed for their commercial use and for research purposes, targeting broad-spectrum invasive pests, which have been difficult to control with conventional pesticides. New delivery systems have also increased the practical use of microbials. For example, a foam delivery system using microbials can reach insects that can hide and escape conventional insecticides.

Novel systems to conserve and enhance impact of natural enemies have been developed, allowing growers to depend more on naturally occurring biocontrol agents and less on pesticide usage, reducing costs. Similar concepts have been transferred to the greenhouse industry whereby domiciles (i.e., banker plants) have been developed that increase and extend the impact of commercially produced natural enemies being used to control specific greenhouse pests. Wild rose plantings that favor a parasitoid of leaf rollers in apples were found to reduce or eliminate the need for pesticide applications in Washington. Wildlife enhancement projects in WA now include planting of wild roses. Progress has been made on permitting of new biocontrol agents for permanent establishment in the US for field crops. Research on the olive fruit fly is an example of excellent progress in identifying, evaluating and introducing promising beneficial agents. Improvements have been made on mass rearing natural enemies, but it wasn't clear how much better these systems are over previous methods.

Problem Statement 2.B: Control

- Insects (Microbial Control)

Review Team Rating (Impact): High

Review Team Assessment:

The projects reported by ARS scientists have produced outcomes that significantly advanced methods for microbial control of pest invertebrates. The project range was impressive and comprehensive, and included those summarized below:

1) Anaerobic storage methods were developed that optimize survival of the biopesticidal fungus *Beauveria bassiana* at 40°C for >1 year. This resulted in EMBRAPA patents.
2) Optimizing rearing methods for ambrosia beetles led to bioassays determining efficacy of two fungal species against the pest.
3) An environmentally stable fungal pathogen was developed and commercially produced for control of soil insect and poultry pests. Another fungal species was produced using the same methods for tick control. Granular formulations of microsclerotia for control of ticks, Asian longhorn beetle and turf insects were developed and commercially licensed.
4) Biocompatible foams were developed for control of cryptic pests such as fruit tree pests and Formosan termites. The foams should also be compatible with organic farming.
5) Application of entomopathogenic nematodes was found to control peach tree pests at rates comparable to multiple chemical control applications. The researchers also developed the use of fire gel to apply nematodes for control of above ground pests.
6) ARS scientists partnered with a commercial nematode producer to increase production efficiency by 200-300%. Two patents and two pending patents resulted, as did interest from other producers.
7) ARS scientists discovered a new bacterium with efficacy against a variety of coleopteran, lepidopteran, and homopteran species as well as mite species, some of which are difficult-to-control piercing-sucking pests. The toxin appears to be heat stable. The bacterium was patented, licensed to two companies, and is now a formulated commercial product.
8) Two hundred baculoviruses were genetically characterized, and virulent strains selected for commercial development.
9) Black vine weevil can be controlled with a combination of a fungus drench and attractants.
10) A combination of a new locally isolated strain of the fungus *B. bassiana* and an insect growth regulator controlled tarnished plant bug, a cotton pest, as effectively as chemical pesticides.
11) A variety of pathogens are being tested alone and in combination with chemical pesticides against the Asian citrus psyllid, which transmits citrus greening disease. Additionally, behavioral studies of the psyllid indicated that area-wide treatment is needed. An RNAi product that disrupts feeding has been patented.

12) Papaya was found to be a successful banker plant for parasitoid rearing and ornamental peppers for predatory mites in greenhouses to control whiteflies and thrips, respectively. The system has been commercially produced.
13) Wheat stem solidity is determined by genotypes that also impact parasitism of the wheat stem sawfly. Selection of solid stems and higher parasitism may be possible.
14) Two plant pathogens causing boll rot in cotton are opportunistically transmitted by polyphagous stink bugs.
15) New rearing methods and artificial diets have reduced the cost of mass rearing predatory mites, beetles and nematodes, cutting costs by half. Genomic research continues on a predatory coccinellid beetle.
16) An assessment of transgenic corn demonstrated protection from the European corn borer and yield increases, both for farmers growing transgenics and neighboring farmers who do not. Economic benefits between 1996 and 2009 are estimated at approx. $7 billion.
17) Bt crops were analyzed for impacts on beneficial non-target insects and the effects were reported as neutral and less disruptive than use of other pesticides. EPA's tier testing for non-target impacts was validated. Cotton refuge requirements were relaxed based on no increased pink bollworm resistance when sterile pink bollworm release was used in combination with transgenics.
18) ARS scientists annually conduct Bt resistance studies on offspring of field collected insects to provide policy data and strategy discussions.

The insect biological control program clearly met all stated goals and relevant action plan criteria, and exceeded expectations in some areas. The program as a whole has significantly advanced the biological knowledge base, technology and success rate for biological control efforts in the US during the project period. ARS scientists are using state-of-the-art research methods to elucidate taxonomic, biological and genetic information about pests and their natural enemies. Novel microbial formulations, application techniques and production innovations have been developed that have the potential to make biological control methods competitive with and, ultimately, more successful than many chemical controls, while also addressing compatibility with chemical treatments within IPM systems. Outcomes of the projects were clearly described, and in most cases, potential or actual impacts were apparent.

Institute collaborations were identified in most of the project reports, and showed strong interactions between ARS scientists and their university and industry collaborators. The researchers and their collaborators have generated patents and have successfully completed technology transfers. Some systems have been commercialized.

Regulatory policy continues to be addressed by monitoring resistance of insects to Bt-modified cotton and corn crops and EPA's tier testing for non-target effects was validated as well. The advances in knowledge and technology have been significant during the 5-year program and have provided underpinnings for accelerated innovation and successes in biological control of pest insects.

There should be concern on the part of ARS regarding loss of invertebrate pathologists and other natural enemies specialists to industry and retirement. ARS scientists are primary leaders of microbial control studies in the US and their numbers have been diminishing at a time when the potential for pest species introductions and concerns about use of chemical controls are increasing. With recent technological advances, the use of natural enemies for pest control has high potential to address many of these problems, and USDA provides opportunities and longer term resources than can universities to develop control programs, but a cadre of well-trained young scientists will be vital to follow up on recent advancements.

NP 304 Component 3 – Protection of Natural Ecosystems

Problem Statement 3.A: Insects

Review Team Rating (Impact): Medium

Review Team Assessment:

The accomplishment report states a research focus on controlling invasive insect pests under this problem statement, including pests impacting natural habitats, forests, city landscapes, and the lumber and nursery industries. [Note: should this and other problem statements in the accomplish report be labeled as “Management” rather than “Control” given the well documented transition from the use of the term “Integrated Control” to “Integrated Management” by the scientific community?] Four projects are highlighted including summaries and references to 21 published studies reporting on:

- Classical biological control, new chemical attractants, improved detection and cultural management of emerald ash borer;
- New tools for early detection of Asian longhorned beetle;
- Advanced polydnavirus-based strategies for disruption of caterpillar pest immune systems; and
- Successful area-wide management of cactus moth.

Eight additional projects are cited in the appendices, including references to more than 100 publications associated with the research.

This research area is critically important. The economic impacts of emerald ash borer alone are expected to exceed billions of dollars across the geographic range of native ash tree species, which encompasses two thirds of the US. Emerald ash borer project outputs and outcomes include establishment of an introduced parasitic wasp in one state, development and implementation of a new mass-production system for parasitoids, discovery and importation to quarantine of a new parasitoid, commercialization of a lower-cost lure for emerald ash borer, an attractant now used to monitor a parasitoid, and a new method for monitoring the extent of the infestation.

Documents provided to support the review are well written, concise and informative. Many important projects and an impressive number of publications, patents and external funding are listed. The four project summaries report valuable new technologies and suggest high productivity tackling key research questions and translating research findings into effective tools.

The problem statement on page 96 in the accomplishment report implies that pesticides would be a viable option, and that biocontrol is not needed, except for three considerations. In reality, there are many additional considerations that merit investments in controls other than pesticides, including resistance, secondary pest outbreaks, etc., that should be referenced to support the need for and benefits from this work.

This problem statement would benefit from including a perspective on the scope of the problem beyond the three insect pests, which were the focus of the research. What proportion of the total problem in the US do the three species represent? In addition to the examples provided, it would be helpful to see an overview of all projects, and a self-assessment as to outputs and outcomes.

The projects for the three insects selected for the summary included a number of very promising technologies. However, with the exception of the award-winning cactus moth project, where a new sterile insect technique for eradication initially showed promise, but because of budget constraints was downgraded to a management program, it was difficult to determine the level of success achieved in relation to the problem, i.e., what impact are the technologies developed expected to have on the problem? For example, is the 75% reduction in emerald ash borer larvae meaningful in terms of population control? Does the new attractant mixture have potential for attract and kill? How do the clusters of girdled trap trees work to lower local borer densities?

Similarly, for the Asian longhorned beetle, the prognosis for long-term control is not clear. Five successful eradications are cited with three ongoing programs mentioned. Are these three expected to be successful? What frequency of new detections is expected?

Outputs are reported with very limited reference to outcomes (cf., desired outcomes listed on page 10 of the action plan). The limited number of outcomes reported are not related to impacts on the overall problem, i.e., if the ultimate outcome is that the pest no longer remains a threat to natural ecosystems, what is the contribution or projected contribution of the output to that goal?

Appendix 1, current research projects and Appendix 2, publications. How do the numbers of projects and publications compare to other project periods, and in relation to funding levels for each project period?

Appendix 3, page 2, patents issued. Of the patents granted, apparently only two have been licensed to commercial partners. Are patent production and licensing valid performance measures, and if so, how do the rates for this reporting period compared to others?

Appendix 3, page 3, external awards. Is this a performance measure? If so, how do the number and amount of external awards compare to other reporting periods? It would be interesting and helpful to see external grants distributed by problem area.

An impact rating of Medium may not reflect actual impacts in this problem area; more information provided on outcomes and summaries of more projects in this problem area may have resulted in a higher impact rating.

Problem Statement 3.B: Terrestrial, Aquatic, and Wetland Weeds

Review Team Rating (Impact): High

Review Team Assessment:

The accomplishment report in this component identified 22 specific projects, each with multiple associated publications to represent the breadth and achievements of the program. The vast majority of these projects included collaborations outside of ARS and multiple authors on the many publications. It was hard to discern whether the ARS scientists played a lead or supporting role unless the reader had prior knowledge of the individuals or the work.

The program was rated as having High impact based on the dramatic success of several of these projects. As would be expected, not all projects were as important and successful, nor were all of the important and successful contributions of ARS scientists represented in the accomplishment report. On balance, the program has made unique and valuable contributions.

This problem area is also somewhat atypical for ARS because the direct connection to agriculture is not always as obvious as with other problem areas. There are elements that are tied directly to protecting the economic productivity of forest and range resources, and the availability of adequate water resources, and per the action plan, there are elements designed simply to reduce environmental harm to natural areas.

Natural areas are managed by a variety of federal (USDA-FS, FWS, BLM, NPS, DOD, etc.), and state agencies that lack the core capacities and pest management expertise resident within ARS and the Land Grant University system. It is appropriate for ARS to apply this expertise to support these other agencies' core mission, while also being careful not to let these activities distract attention or resources from the ARS core mission as stated in the 2006-2011 ARS Strategic Plan, objective 4.2. (e.g., Reduce the Number, Severity and Distribution of Agricultural Pest and Disease Outbreaks). This is a service function that requires extensive collaboration outside of typical USDA audiences. It is apparent that this has been accomplished, and that there is significant collaboration with universities, and other federal and state agencies.

The primary competency of this program is in insect-mediated biological control as illustrated by more than half of the projects in the accomplishment report using this approach (*Melaleuca*, old world climbing fern, *Arundo donax*, leafy spurge, salt cedar, water hyacinth, yellow star thistle, scotch broom, air potato, Chinese tallow and tropical soda apple). The dramatic success of this approach to manage *Melaleuca* and old world climbing fern in Florida demonstrate high impact. These two examples also illustrate the value of program continuity that ARS can provide over sustained periods. The success achieved with *Melaleuca* took over three decades. Success with Old World climbing fern was evident in about one decade.

The success with insect-based biocontrol is dependent on several core capacities that support each other. These include the network of overseas biocontrol labs, the mass rearing capability and capacity, the dedicated expertise dispersed throughout the country, and the ability to sustain programs over long time frames. The specific applications of these core capacities may change, but together they represent a unique, valuable and strategic resource that are of paramount importance to our national weed biological control efforts.

The program also incorporates several other important approaches that are not as dominant as the insect based biocontrol work. These include plant pathogen-based biocontrol, (Eurasian milfoil and statistical modeling of genetic relationships among target and non-target species), use of molecular and genetic tools to identify subtle differences in invasive species and control agents, elucidating mechanisms of invasion (swallow-worts), the ecology of invasions

(Ecologically-based Invasive Plant Management, EBIPM, in the Great Basin) and integrated control strategies (scotch broom and *Ludwigia*) including very limited use of herbicides.

The success of the insect-based biocontrol overshadows the other elements of the program, and may inadvertently inhibit integration of multiple control approaches. When all you have is a hammer, everything looks like a nail. The general consensus is that the invasive plant problems are more difficult than can be solved with a single tool, and the program is at risk of becoming myopic in the strategies pursued. There are certainly opportunities for greater collaboration across multiple disciplines to amplify the success of this program.

The regulatory processes associated with biocontrol, whether insect or plant pathogen based, are a frustration to scientists pursuing this work and they add significant time to the process between research and demonstrable impact. This applies equally to basic work on natural biocides, which must go through different but equally daunting regulatory reviews.

It also appears that the program has not adequately addressed the objective of Early Detection and Rapid Response for invasive plants, although it does seem to be part of the strategy for invasive insects. We will arguably face a steady stream of new invasive species as a collateral cost of global trade. Today's program is heavily focused on management of established and damaging invasions, but there is much more that could be done to help predict, prevent, interdict, detect and destroy invasive plant populations before they are established.

NP 304 Component 4 – Protection of Post-Harvest Commodities and Quarantine

Problem Statement 4.A: Insect Pests of Fresh Commodities

Review Team Rating (Impact): Medium

Review Team Assessment:

Component 4.A projects are crucial to U.S. commodity producers regarding exclusion and eradication facilitating production, export and domestic movement. They are also meant to put tools in the hands of action agencies for use in exclusion and eradication to facilitate imports, exports, and domestic movement. There were 61 actions listed in the action plan, and many could not be linked to appendix papers or to the accomplishment report. It is realized that the demand in this dynamic area is overwhelming. Paper titles indicated broad areas of microbial and arthropod quarantine control, post-harvest quality management, SIT, biocontrol, host status, wide area control and systems approach, monitoring, surveillance, treatments, and other sub-categories. Selected accomplishments include a proposed systems approach in Hawaii for fruit fly management in 'Sharwil' avocado, generic quarantine irradiation treatments, quarantine treatments for *Drosophila suzukii* for export strawberries and cherries, and phosphine treatments for thrips and aphids for export lettuce. These examples are significant because of the great near-term impact they have had on trade.

This team has had significant impact on the push to better understand the sterile insect technique method and improve its efficiency. There were several projects that addressed this issue, and the outcomes are significant to control fruit fly pests. For example, the diet and JH interactions project have led to a better understanding of raising males that are competitive during matings. Action items related to detection of hidden pests, attractants, and bait stations for modeling add to the effectiveness of the overall rating of the component. Reviewers found the component lacking in deliverables in the area of moths and external quarantine arthropods, which were two of four areas in the action plan problem statement. If this work was to be there, it was lacking from the report. These are two critical areas facing the industries that produce fresh commodities, and it was not noted in the report. The reviewers also want to see mites and gastropods mentioned and prioritized as targets in the Action Plan.

ARS made strides in the action areas of fruit fly and moth lures and attractants, diet technology and genetic manipulation related to SIT, and biocontrol studies. These areas are critical, and have high impact in supporting systems approaches and should continue. Work was also evident in postharvest quality assessment and host status determination. Some advances were also made in diversifying the number of postharvest quarantine treatment chemicals for use by investigating phosphine, ozone, hypobarics, and other little-used methods on a limited number of commodities. ARS is the leader in discovering and investigating methyl bromide alternatives for use by industry in the postharvest quarantine area. The action plan lists this in general terms, but made no mention of it in Component 4.A.

Two action areas of critical importance are not well developed: pest inspection/detection methods and systems approach applications. A systems approach is a group of multiple separate control measures (, biocontrol, host status) applied serially or together that make a total system, and provide an acceptable level of phytosanitary protection against a pest: there is a need for methods to determine the overall efficacy of the system. Improved pest detection is needed during inspection of commodities at ports of entry. For example, this not only pertains to diagnostics applied after a lesion is found on a fruit, but also to detecting a fruit with lesions that is buried within a shipment load. Methods applicable to detecting a pest in a container would be desirable. Currently manual sampling and visual inspection are the main methods. While trade increases and manpower hours decrease, inspection efficiency is decreasing, allowing greater risk of pest introductions. Acoustics have been investigated for years and have had only very limited use and none at the ports. There are other methods (such as VOC and NIR) that were described in a 2013 DHS S&T report on cutting edge inspection methods where proof of concept testing could yield high impact. Systems approaches have been applied on a limited basis by regulatory agencies, but the level of efficacy has not been determined. The groundwork was laid by ARS decades ago, but little progress has occurred in applying these methods. There is some interesting work being started by ARS scientists at Parlier and Hilo to further quantify effects so that regulators will have confidence in and a method to apply the measures. Action agencies are moving increasingly toward using systems approaches because chemical and mechanical methods in the form of stand-alone measures have become more problematic, and more generic mitigations are needed. An increase of research on application of systems approaches at the commodity/country/pest complex level could yield high impact ingoing forward. ARS is in a unique position to take the lead and produce comprehensive studies.

Lastly, reviewers note a considerable number of papers where a treatment was used for one commodity and pest. Now that there is a large body of specific pest/treatment/commodity combinations on the books, it would be beneficial to simplify and move toward generic treatments, which are applicable to a wide variety of pests and commodities. As an example, ‘generic quarantine irradiation treatments’, was cited above.

Problem Statement 4.B: Insect Pests of Durable (Stored and Processed) Commodities

Review Team Rating (Impact): Medium-High

Review Team Assessment:

The breadth and the depth of the research publications listed in the appendix are impressive for this component. These scientists are doing excellent work and have made significant progress toward many action items. Many, as noted in the appendix, are doing applied work that will have immediate impact on the industries and individuals that need this information. Several of the projects are long-term in nature, and require more than a 5-year project period to evaluate significance.

The most troubling issue is the disconnect between the reported accomplishments and the action plan. In a few cases, the accomplishments were insufficient to determine impact, although the appendix suggested significant progress in developing treatment tools for stored product producers. Some projects only listed outputs for early years (for example selfish gene discovered – 08 and 09). It is unclear if these projects are continuing or have come to a standstill due to personnel, budget or other reasons. This basic study may eventually have significant research implications, but there is little prospect of near-term impact on controlling stored product pests indicated if the projects have stalled.

Of the projects listed in the accomplishment report, only the projects on radio frequency detection of cowpea weevils and the use of pheromones to manage Indianmeal moth were mentioned in the action plan. Many other accomplishments were noted that were not listed in the action plan and many action plan projects were not mentioned in the accomplishment report. For example, the methyl bromide alternative development for grapes and cherries directly connect with the action plan for optimizing technologies for control, however reviewers thought that this project should be in Component 4A as fresh commodities. Areas in the action plan not evident in the accomplishment report are organic and biological control, emerging pests and outdoor pest population influence.

Emerging pests are a critical concern of durable commodities, but a search of the accomplishment report indicated no publications or work directly related to a major pest of quarantine concern, Khapra beetle. Incidence reports of this insect have dramatically increased in the past few years, and the establishment of this pest in the US would be devastating to the grain and food industries. The reviewers are aware of a new collaboration between ARS, APHIS and Kansas State University on new treatments for Khapra beetle. This research will have high impact for action agencies and industries, and should be emphasized in the next action plan.

Areas that were missing in the accomplishment report include work on the three major grain crops (wheat, corn, rice) – a major concern given the sizable import and export markets. Although one of the major pests (*Tribolium*) is included in three of the four projects, these projects are fundamental research with long-term implications. They do not have immediate significance on issues concerning these durable commodities.

Other areas noted in the action plan that should have been addressed in the accomplishment report include pest detection through improved sampling methods, sanitation, and alternative treatments for methyl bromide, possible blockage of sulfuryl fluoride, and of major concern is the rise of resistance to phosphine. This could be devastating to the grain industry as phosphine is the primary method to treat stored grain. Emphasizing work in this area could have significant implications for producers and action agencies.

Continue working with industry to assist the commercial sector with alternatives, research on sampling low level populations, fundamental biology of invasive species, and alternative controls as phosphine becomes less viable because of resistance development. Also, although inspection and detection methods have been stressed as a need, there is only a small amount of research completed in this area. Augmenting effort in this area could have positive implications for producers and action agencies. Treatment and host status work on *Drosophila suzukii* on cherries and grapes belongs in 4.A. Move the basic research to a fundamental component – it is a mismatch with the other needs. Strengthen the nutrigenomics and basic biology to understand how various crops impact insect development and control. Pest detection is still a critical need.

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